Progress on S53 for Rotary Gear Actuators

ESTCP Project WP-0619

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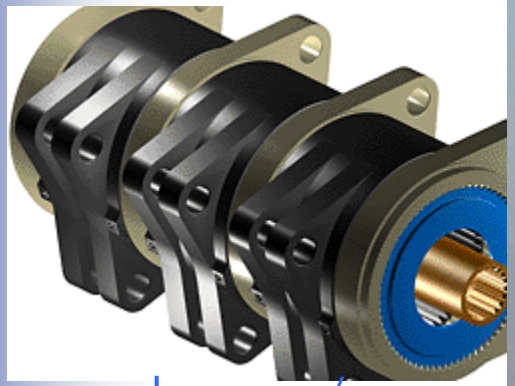
Team

- Ogden ALC, Ryan Josephson (PI)
- QuesTek Innovations LLC (steel design)
- General Atomics (testing)
- Lockheed-Martin (F-35 prime)
- Moog (WFAS RGA manufacturer)
- Curtiss-Wright (LEFAS RGA manufacturer)
- BAE Systems (galvanic testing)
- Rowan Technology Group (coordination, cost analysis)

What is an RGA?



www.zakgear.com/

Geared system to rotate one set of tabs relative to another

Used on F-18 to operate wing fold

Hazmat Alternatives

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RGAs on F-35 Lightning II

RGAs used for

- Wing fold actuator system (WFAS)
  - Carrier variant
- Leading edge flap actuator system (LEFAS)
  - All variants

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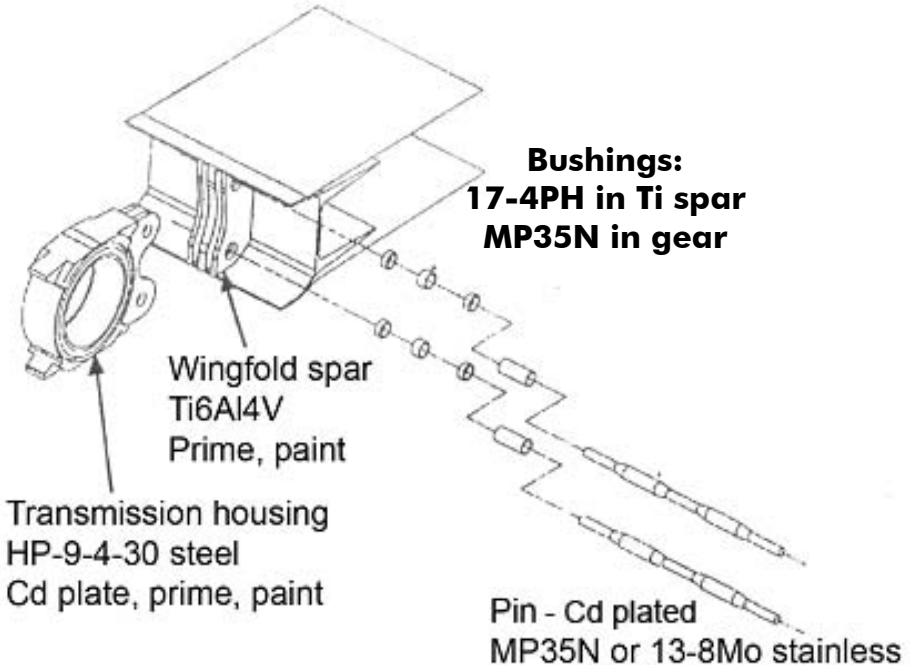
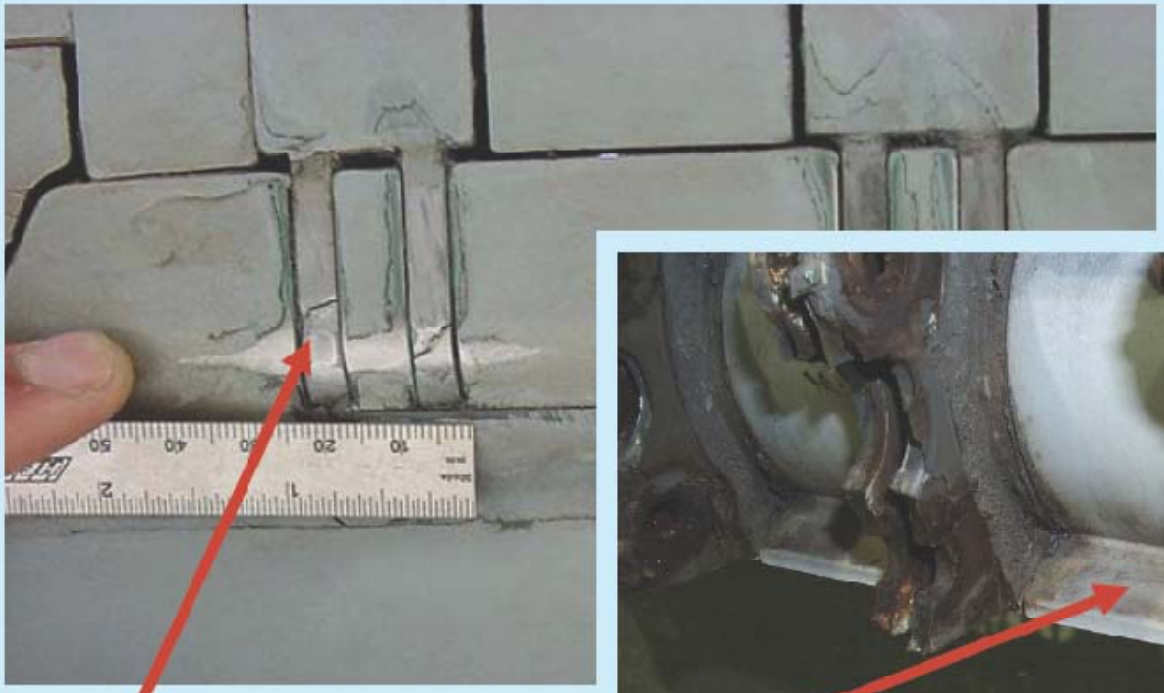
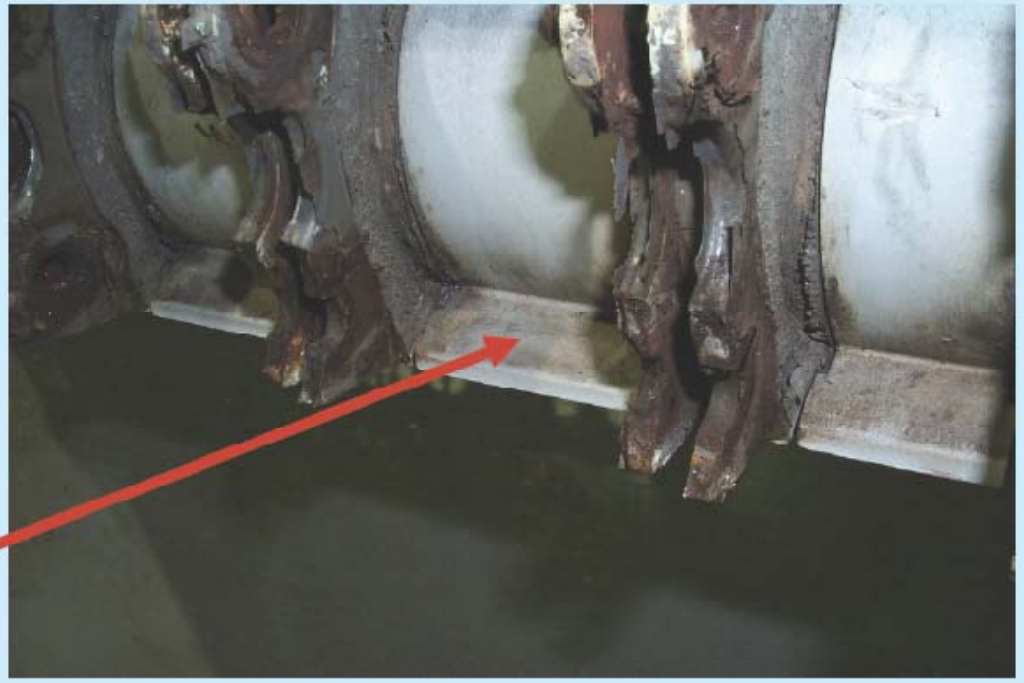
Design materials

- MP35N Ni alloy rods
- HP-9-4-30 or 4340 high strength steel gears (Cd plated)
- 17-4PH stainless bushings
- Ti wing spar
- Bad galvanic couples



Galvanic corrosion of current system



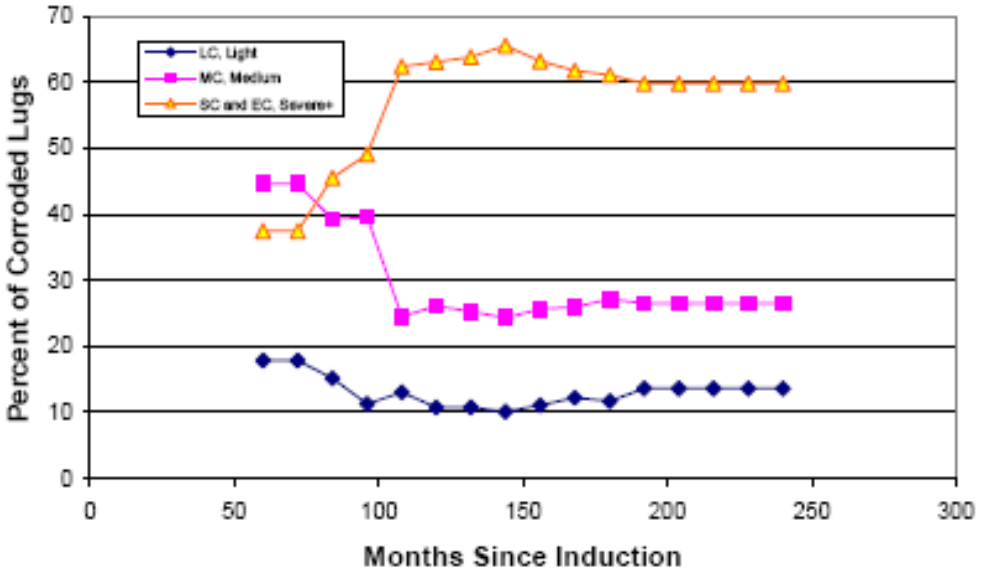


Cracks

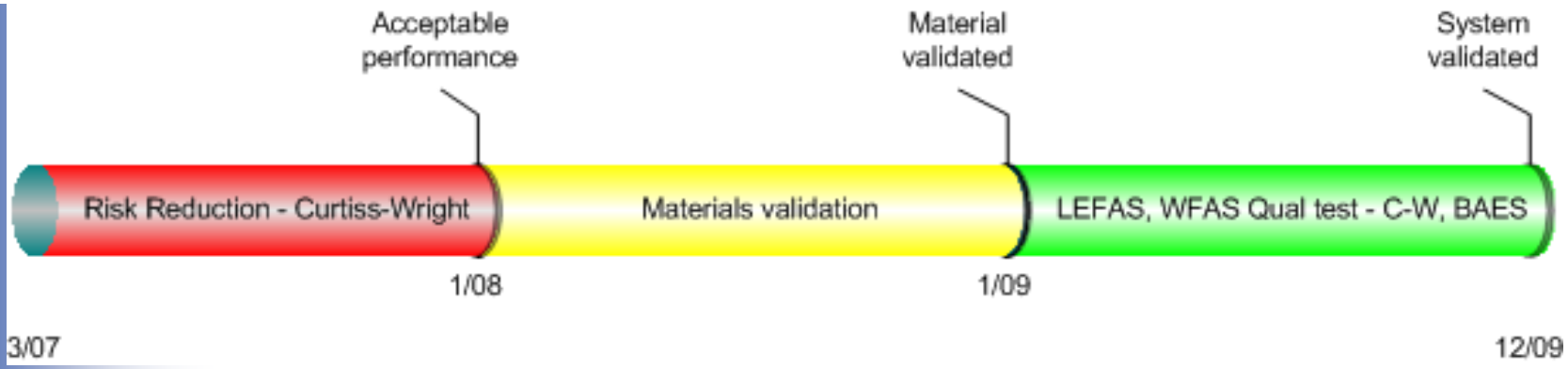
Missing Lugs

Extent of the problem

- This is a problem with all F-18 lugs
  - Matter of severity
  - Cracks come from corrosion pits
- Want to avoid this problem on F-35
- S53, being a CRES alloy, will not have progressive corrosion
  - But could still have pitting corrosion leading to fatigue
- S53 also has much better K_{1C} and K_{1SCC} so cracks will not grow as fast



Program design

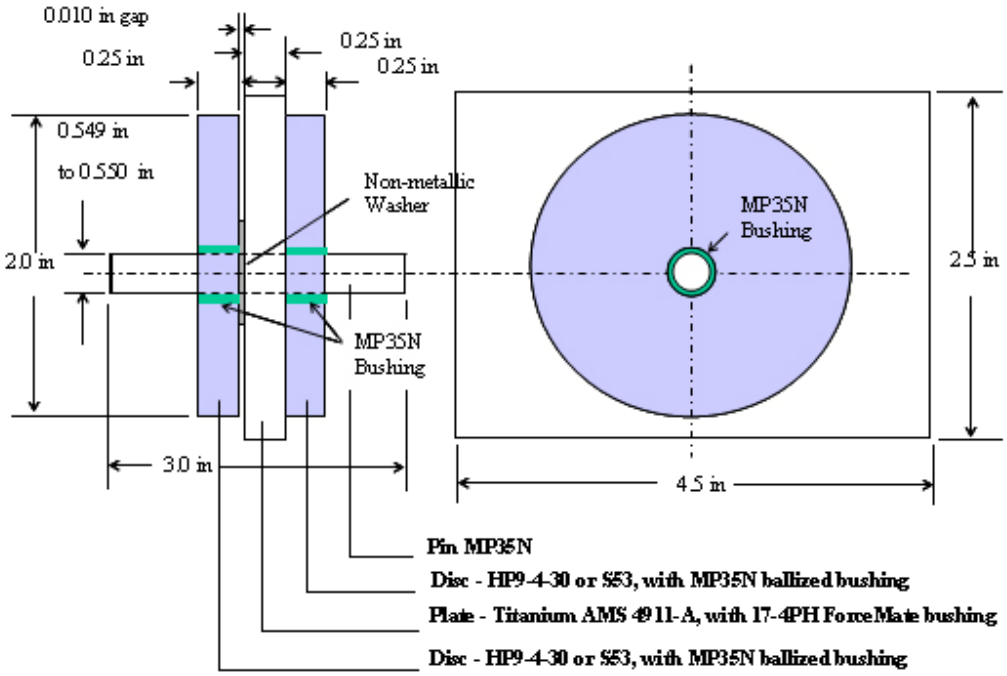


- Because S53 designed for landing gear, not RGAs, program defined 1-year Risk Reduction
  - Corrosion (galvanic, crevice) at BAES in UK to match previous F-35 LEFAS testing

Parallel F-35 Program Office test program at Curtiss-Wright

- C-W testing of growth on heat treating showed growth uniform and predictable
- Machining of test parts showed S53 is machinable in C-W shops
  - But must be sent out for heat treating as uses cryogenic steps
- C-W contracted to manufacture S53 LEFAS as demonstration and carry out mechanical testing of coupons

STREAMLINED CORROSION TESTING OF S53 FOR RGAs



Components

- **Pin MP35N – refurbished from previous trials**
- **Titanium plate with 17-4PH bush – also refurbished from previous trials**
- **Gears made from HP9-4-30 or S53 with MP35N bushes**

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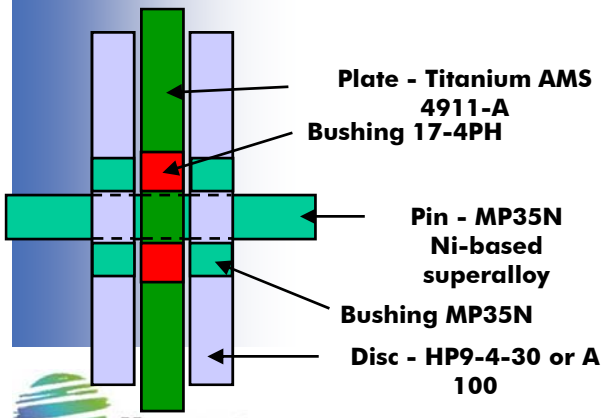
BAE SYSTEMS

ASTM G85, SO_2 salt spray testing completed October 22, 2007



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End of test (14 days, 336 hr)

Test #1, 2 HP9-4-30, Cd plated

Delamination of paint near bushing

No corrosion of HP9-4-30

Test #4, 5 S53, Cd plated

Delamination of paint near bushing

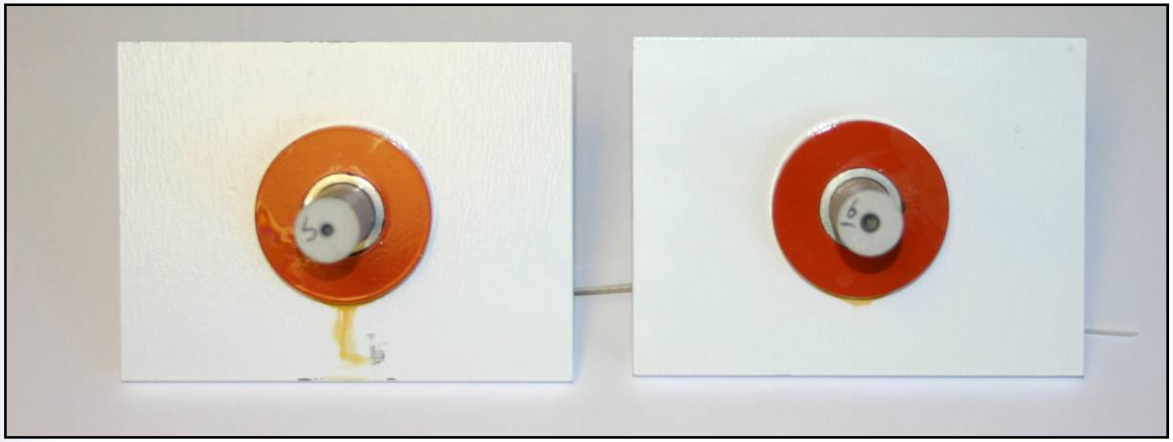
No corrosion of S53

Cd plating does a good job of corrosion protection.
But adhesion of non-Cr primer is poor (needs better surface prep, vendors need to develop experience)

End of test (14 days, 336 hr)

Final Test Results – after 14 days

Test #3 S53, Boegel AC131 (Not Cd plated)



No delamination of paint – very good paint adhesion to AC131

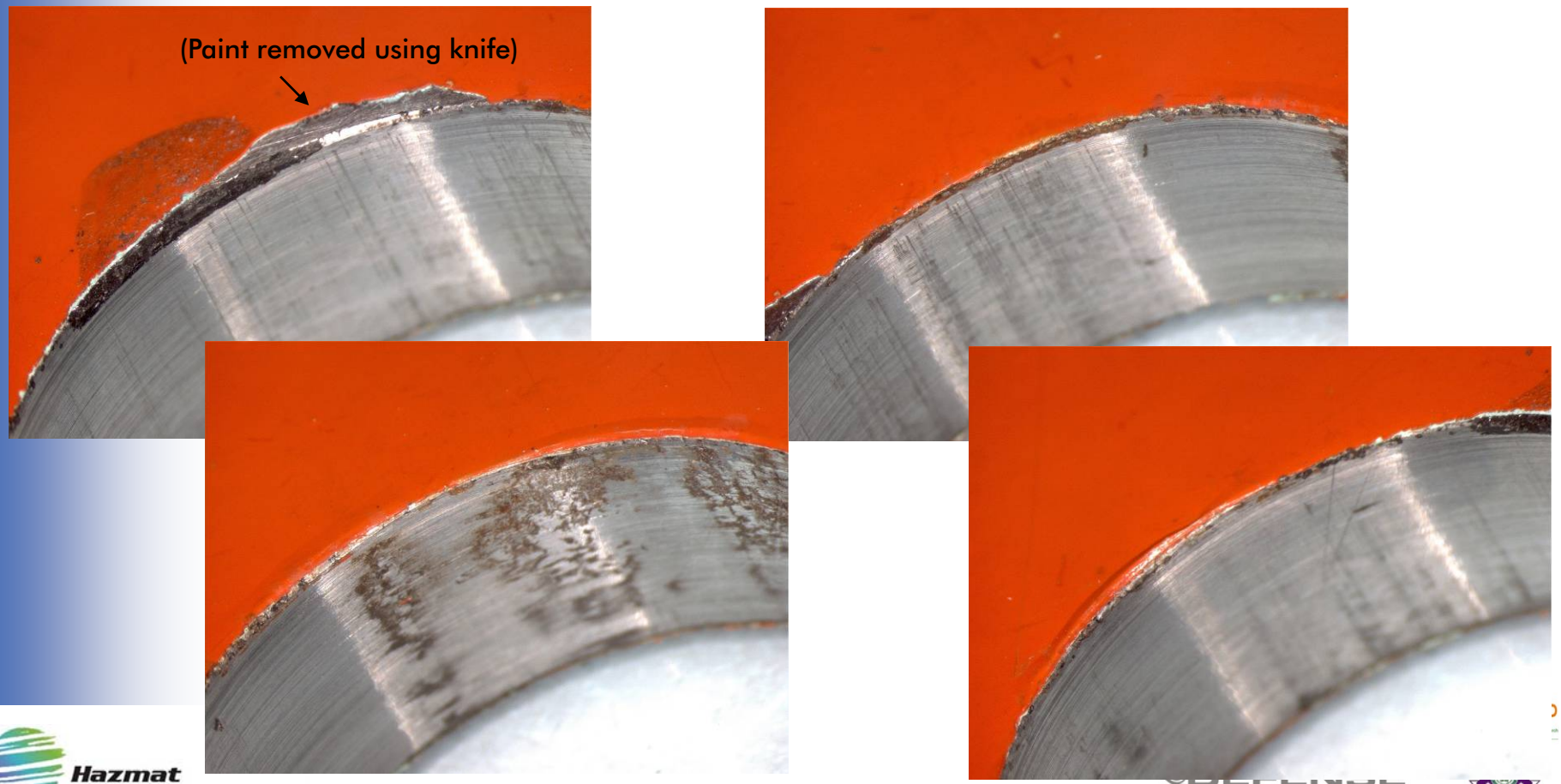
Slight corrosion of S53, on exposed edge between bushing and paint (edge exposed because of limits to masking accuracy)

No corrosion found between S53 and bushing

This is a very encouraging result

Final Test Results – after 14 days

S53, Boegel (no Cd plate) – bush removed - Outer surface



Conclusion on galvanic/crevice G85 corrosion testing

- Non-Cr primed and painted S53 similar to Cd-plated HP9-4-30
  - If Cd is undamaged
  - S53 much better if Cd is imperfect or damaged
- WFAS and LEFAS made with S53 gears that are only Passivated, Non-Cr Primed and Painted should pass Navy-required F-35 corrosion testing with performance seen in this test program

Next step – Materials validation

Corrosion

- Galvanic/crevice corrosion
  - Current baseline
  - Current baseline + AlumiPlate
  - S53 passivated, AC130, primed, painted
  - Concentrate on **damage tolerance**
    - In real world corrosion protection system damage is inevitable

Mechanical

- Paper study evaluation of alternative high strength CRES alloys
  - To be sure S53 makes most sense
- Gear durability, tooth fatigue, RCF
  - Core hardness probably sufficient
  - May need nitrided case

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Qualification

- MMPDS listing and Class A allowables available shortly
- Full materials test results available shortly in Final Report of ESTCP S53 Landing Gear project
- Qualification of F-35 RGAs
  - Full LEFAS/WFAS units to be manufactured from S53
  - G85 SO_2 salt fog testing of full unit (requirement for all F-35 systems)
  - Full functional rig testing
  - If successful and cost-effective will enter program in LRIP

Technology Transfer

- RGA must be bushed to reduce galvanic attack
  - This increases the cost of the system
  - S53 is then becomes a cost reduction for new programs
  - Reduction of corrosion fatigue failures will be a cost reduction for legacy programs
- Tech transfer through Moog (WFAS) and Curtiss-Wright (LEFAS), who are manufacturers for all current systems on F-35, F-22 and F-18
  - If successful will initially enter production through F-35 LRIP
  - Would be drop-in replacement for F-18 WFAS
    - Qualification required
- Initial implementation may be made through use of S53 for F-35 jack, which uses the same type of RGA
  - And is not, of course, flight-critical!
  - But weaker cost driver